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Experience of the Armed Forces Institute of Pathology in Aircraft Accident Investigation, 1956-1960*

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SINCE 1956, the Aviation and Forensic Pathology Section and the Aerospace Pathology Branch of the Armed Forces Institute of Pathology (AFIP) have studied and reviewed approximately 2,000 cases of military and civilian personnel involved in fatal aircraft accidents. AFIP personnel have investigated 28 military and 12 civilian aircraft accidents at the crash sites.

Many problems confront those interested in aircraft accident investigation. Accident investigation in remote areas by physicians and pathologists with little interest have failed to yield conclusive results in many cases. Failure of cooperation between the Air Force Flight Surgeon and pathologists of civilian and other military services has resulted in lack of coordination in the reconstruction of the material and human factors which resulted in the fatal accident.

The introduction of commercial jets in British air transportation in 1954 had, as we recall, tragic results. The Comet accidents appalled those planning for the future development of large jet aircraft transportation. The report by Armstrong et al.[1] in 1955 of the pathologic investigation of the passengers in the aircraft, along with the reconstruction of the wreckage recovered from one of the Comet aircraft and testing of other similar type aircraft, revealed the true nature of the structural defect which resulted in the type of trauma the passengers suffered.

This investigation provided the stimulus for a meeting held at the AFIP in March 1955, which was attended by aviation representatives of the Armed Forces of the United States, Canada, and the United Kingdom. The purpose of this meeting was to explore ways and means of counteracting the rising toll of aircraft accident fatalities in the three represented nations. As a result of the meeting, the Department of Defense[2] directed the establishment of the Joint Committee on Aviation Pathology, with the AFIP as the central coordinating facility for the investigation of the pathology of fatal cases in aircraft accidents. The AFIP then established the Aviation Pathology Section, integrating it with the already existing Forensic Pathology Section. Because of the large number of cases, it became necessary in 1959 to reorganize the Section, and a new Division was created:

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the Military Environmental Pathology Division, with three Branches, the Aerospace Pathology Branch, the Forensic Pathology Branch, and Wound Ballistic Branch.

Realizing the important role of biochemical support for the study of aircraft accident fatalities, a toxicology laboratory was established in the Aerospace Pathology Branch in 1956. This laboratory utilizes very sensitive tests for the analysis of blood and tissue to determine levels of toxic substances to which flying personnel may be exposed.

The AFIP personnel studying aircraft accidents have contributed a considerable amount of the literature relating pathology to aircraft accident fatalities.

Early in these investigations it was obvious that for a total understanding of the "man-aircraft" relationship three major factors must be considered: (1) environmental factors, (2) traumatic factors, and (3) pre-existing disease factors. Table 1 presents some important items to be considered under the major factors.

TABLE 1

FACTORS AFFECTING THE "MAN-AIRCRAFT" RELATIONSHIP

Environmental factors
Altitude—Hypoxia, decompression
Speed—G forces, spatial disorientation, blast
Toxins—Carbon monoxide, fuels, odors
Temperature—Excessive heat, cold, humidity
Noise—Auditory effects, vibration
Stress—Pathology of terror
Traumatic factors
Protective equipment
Escape
Aircraft design
Pre-existing disease

Experience with aircraft accidents has brought us to certain obvious conclusions. First, flying at high altitudes and great speeds requires the construction of the best aircraft possible, with all the necessary equipment provided to render an environment within the machine itself that will sustain a living human being safe from the physiologic hazards present only inches away. Second, if escape from the aircraft becomes a necessity, adequate devices must be provided to assure safe exit and descent. Third, if pre-existing disease is present and undetected, the role it played in any aircraft accident must be determined.

ENVIRONMENTAL FACTORS

Hypoxia. Among the environmental factors, one of the most important problems is the postmortem diagnosis of acute antemortem hypoxia. The lack of suitable histopathologic criteria prompted studies at the Royal Canadian Air Force Institute of Aviation Medicine[3] and later at the School of Aviation Medicine, U. S. Air Force, Aerospace Medical Center,[4] to explore some means of detecting antemortem hypoxia in postmortem tissue. Through this joint effort, a test on postmortem tissue was devised utilizing the content of lactic acid in the postmortem central nervous system (CNS) tissue to indicate the existence of acute antemortem hypoxia. This test looked promising in experimental animals and, therefore, a program was initiated at the AFIP to explore the value of determining the level of lactic acid in postmortem CNS tissue in aircraft accident fatalities.

Frozen, nonfixed tissue from victims of aircraft accidents is submitted to the Armed Forces Institute of Pathology by the U. S. Air Force, Navy, and Army. Since October 1956, the brain lactic acid level has been determined in these cases. Within the experimental confines of the test, lactic acid levels over 200 mg. % in brain tissue were considered indicative of hypoxia, although the elevated value did not distinguish between the causes of the hypoxia.[5,6] In 930 aircraft accident cases in which this test was routinely performed at the AFIP from October 1956 to November 1960, there were 86 instances in which a value over 200 mg. % was obtained. In 7 instances there was definite evidence that the elevation was due to altitude hypoxia, in 42 there was history of short survival in a shock state following the accident, in 9 suffocation was the cause, in 15 instances drowning was responsible, in 5 no history was available, in 5 cases there was doubt as to the cause, and ir 1 there was a

possibility of either hyperventilation or hypoxia.[7] One case illustrates the value of this test.

Case 1 (AFIP Accession No. 916567). A Navy pilot with 2,030 hours' total flight time took off in a Navy T2V trainer at 1005. Thirty-eight minutes later, the pilot made a VFR position report. Altitude was 35,000 feet. Sixty-six minutes later he made another routine VFR position report. Seven minutes after the latter position report, witnesses stated they observed an aircraft descending and apparently out of control. The airplane crashed in a wooded area at 1117, the time the clock in the front cockpit stopped. Examination of the impact area indicated a steep downward path 60 to 70 degrees, with left wing down and nose down on impact. The wreckage was in one general area and formed a pattern indicative of striking the ground in a left spin. The aircraft burned after impact. There was no evidence that the pilot attempted to eject.

Pathology examination: An autopsy was performed at Bethesda Naval Hospital. The brain was totally avulsed, and the body was severely burned. There was very severe trauma, with partial amputation of all limbs.

Spinal cord tissue was removed and sent to the AFIP Toxicology Laboratory for lactic acid determination. The lactic acid level was reported at 270 mg. %. This indicated that the pilot was probably incapacitated due to hypoxia. The medical officer's thorough examination of the accident site indicated that there was no attempt to eject. In his opinion the pilot was probably developing hypoxia over a period of 20 to 30 minutes prior to the time of the crash.

In previous years without this procedure for determination of lactic acid in central nervous system tissue, this accident would probably have been placed in the category of "cause undetermined." The Naval investigating board's examination revealed no mechanical failure.

Toxins. A great deal of time has been devoted to the environmental problem of toxins, e.g., carbon monoxide. Since blood frequently is not available for analysis in aircraft accident fatalities, it is necessary to use tissue for the determination of carbon monoxide. At present, the AFIP is utilizing gas-solid chromatography for the analysis of carbon monoxide.[8,9] This apparatus will separate any unknown mixture of gases into its component gases and release them at separate time intervals. The per cent carboxyhemoglobin (COHb) in an aqueous extract of tissue is determined by comparing the peak heights of CO content and CO capacity. The use of gas chromatography has proved to be accurate, sensitive, and specific for CO. In the period from 1 May 1957 to 31 October 1960, 1,303 cases of aircraft accident fatalities were examined at the AFIP for the presence of carbon monoxide (Table 2). Of these cases, 126 showed CO levels of 10% COHb or over. All cases showing COHb levels over 10% saturation have been carefully analyzed and evaluated on the basis of autopsy protocols and accident histories. All aircraft accident victims with COHb levels above 10% saturation were shown to have been alive at the time of a fire, either in-flight or subsequent to impact. In no case of "cause undetermined" accidents was there an unexplained elevation of COHb.

TABLE 2

CARBON MONOXIDE IN AIRCRAFT ACCIDENT FATALITIES
1 May 1957 to 1 April 1960

Saturation	Number of Cases	Per Cent
Less than 10%	1,177	90.3
10–20%	77	5.9
21–30%	20	1.5
31% and over	29	2.3
TOTAL	1,303	

Carboxyhemoglobin levels between 6% and 9% saturation indicate the possibility that the subject was alive at the time of exposure to fire. However, these cases should be cautiously evaluated, because it is known that heavy smoking can raise the carboxyhemoglobin to similar levels. Extensive fragmentation and postmortem incineration of tissues subsequent to explosive impact

forces do not elevate the carboxyhemoglobin saturations. In this 2-year period, no cases were found in which carbon monoxide intoxication has been implicated as the cause of an aircraft accident. Carbon monoxide analyses are still performed routinely, however, on all aircraft accident fatalities to determine whether or not the individuals were alive or dead at the time of the fire. This information is useful in determining the sequence of events in an accident and in analyzing the problems of escape from a damaged aircraft.

Traumatic Factors

In the consideration of traumatic factors we are concerned primarily with the protective equipment within the aircraft, the escape mechanism, and the aircraft design. We very recently had an interesting case involving one of our latest types of aircraft. This presents a problem of failure of protective equipment with which we are faced now and which might well have been prevented by previous experimental studies performed in 1957 at the Aero Medical Laboratory. Experiments using chimpanzees in rapid acceleration and deceleration were performed. At speeds well above Mach 1.0 the animals were rapidly decelerated and underwent the stress of 80 to 100 G. The animals suffered severe windblast burns in exposed areas, and protective clothing was ripped away. A majority of them did not survive.

Case 2 (AFIP Accession No. 962491). A B-58 aircraft being flown by a civilian test crew was flying at 42,000 feet near thunderstorm activity with cloud tops reaching an elevation of 50,000 feet. Six minutes before crash the pilot reported no difficulty and stated the intention of beginning an acceleration run. The aircraft impacted in an inverted attitude at an estimated 70-degree angle at a speed of Mach 1.2 to 1.4, disintegrating in a crater 60 feet in diameter and 30 feet deep. Witnesses stated that all three parachutes opened normally and descent was at normal speed. The members of the investigating board estimated that the ejection of the three crew members took place over a period of 11 seconds and from altitude levels of from 26,000 to 16,000 feet.

At autopsy the significant findings were as follows (for clarity, only one crew member's injuries will be described): Deep macerated pit marks over front and sides of face and body, separation of pubic symphysis, fractures of left leg, and dislocation of right knee. The flying clothing was ripped off, and severe edema of periorbital region was present. Abdominal and thoracic organs were intact. Microscopic examination revealed severe cerebral congestion and edema with multiple petechial hemorrhages. The cause of death was the severe cerebral damage and multiple fractures with hemorrhage in the pelvic tissues.

A summary of the aircraft accident was prepared by Colonel John P. Stapp, USAF, MC. The following is an extract of Colonel Stapp's comments.

"The head rest shows multiple screwhead punctures indicating rapid side to side buffeting of head with helmet screws puncturing the head rest. The separation of the pubic symphysis, left leg fractures and right knee dislocation correspond to failure of the leg retaining straps with upward and backward flailing of the legs. Boot polish markings were found on the left of the seat and head rest. The ripping of the flying clothing indicates an initial windblast pressure of about 1,000–1,500 pounds per square foot. The remaining clothing was tattered and punctured through all layers by hailstone impacts. The upper facial edema is consistent with initial abrupt, forward-facing deceleration. The autopsy findings regarding cause of death are concurred in."

Colonel Stapp's comments reconstructed the entire accident sequence. He further indicated that one crew member was pulled from his seat by a force estimated at 6,000 pounds or more by windblast, prematurely deploying the parachute. The conclusions were that "injuries caused by failure of head, arm, and leg restraints with resultant flailing in windblast higher than Mach 1 and between 1,000 and 1,500 Q [pounds per square foot] were the cause of death as determined from the autopsy."

Pre-Existing Disease

The most frequent pre-existing disease process found in fatal aircraft accidents is some degree of coronary artery atherosclerosis. This aspect of AFIP experience has been well covered by Glantz and Stembridge.[10] More recently we have encountered an increase in private light plane fatalities involving men in the late fourth and fifth decades of life. To cite one case briefly, a 54-year-old pilot was flying his own light plane, which was observed to assume unusual attitudes. Shortly thereafter the pilot was seen to be slumped forward over the controls by another pilot flying nearby. The plane crashed and burned. Autopsy revealed an old thrombus in the left coronary artery, with myocardial fibrosis. Acute coronary insufficiency was the most likely cause of the accident, in view of the history given by the eyewitness. It was later learned that the pilot went to one physician for his flying examination and to another physician for his heart disease.

Discussion

These case reports present a brief sample of the multitude of fatal aircraft accidents we have encountered. The loss in personnel from the humanitarian aspect is immeasurable. The materiel loss is astounding.

The case of hypoxia reveals one area in which pathology and toxicology are making inroads into the realm of the "cause undetermined" accident. The supersonic aircraft accident investigation report reveals the lucid picture that can be drawn from the autopsy and a thorough investigation of remnants of an aircraft. This can only be done when the flight surgeon and the pathologist perform the investigation with one aim—to determine the sequence of events that led to the fatal trauma. The investigation must elucidate the necessary modifications in the aircraft and crew survival equipment to prevent a future similar fatality.

We believe, after 5 years of experience in the pathology of aircraft accident fatalities, that we have contributed a better understanding of the total "man-aircraft" relationship under adverse conditions.

We are justified in this belief by a recent increase in interest in our work by military and civilian pathologists in this country. We now have four foreign allied officers in the Aerospace Pathology Branch reviewing our material; one is a surgeon general, one an assistant surgeon general, and two are flight surgeons. We have much to learn from our cases in accession, and this mass of information must be reviewed diligently. With our experience in firm grasp, we must now face a new and more exotic challenge—the pathology of outer space.

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